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EXPERIMENTS WITH STOCKS FOR CITRUS

BY

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CITRUS EXPERIMENT STATION

POMOLOGY

W. W. BONNS. W. M. MERTZ.

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* In co-operation with office of Public Roads and Rural Engineering, U. S. Department of Agriculture.

EXPERIMENTS WITH STOCKS FOR CITRUS*

By W. W. BONNS and W. M. MERTZ

INTRODUCTION

Citriculture, like other branches of agricultural art dealing with the production of tree fruits, is fundamentally concerned with certain problems of plant propagation. Fruit varieties of desirable qualities and commercial value must be perpetuated; why this end cannot generally be attained through the production of seed from cross-pollinated fruits, the Mendelian discovery has only recently explained. Practical attainment, however, preceded the discovery by centuries, and the arts of budding and grafting have preserved the desired fruit varieties through succeeding generations.

The use of such asexual methods of propagation introduced into horticulture the scientific problem of the relation and interaction of stock and scion. The literature of horticulture and the sciences bearing thereon are full of observations and deductions relating to this question. Much of the early work has little scientific weight; later investigations, chiefly in the field of botany, have attacked the problem in a truly scientific manner, with results of great interest and significance. A survey of the literature, however, at least in so far as it relates to tree fruits, leads to the conclusion that little specific information based upon definite, careful experiments with well-defined conditions, is available.[1] Especially noticeable is the paucity of orchard experiments of sufficient size.

The very evident importance of definite knowledge regarding the various stocks for citrus and the relations of the stock to the several species and varieties grown for commerce in regard to optimum growth and production, should make emphasis of the subject unnecessary. As a matter of fact, there is probably no factor connected with his business that has received less thought from the average California citrus grower. The phenomenal growth of the industry, its beginnings in the profitable sweet seedling groves, and the subsequent great demand for nursery stock, has resulted in an almost universal use of two roots

* Paper No. 11, Citrus Experiment Station, College of Agriculture, University of California, Riverside, California.

[1] For a review of this subject see Prof. U. P. Hedrick's article "Stocks for Fruit Trees," Monthly Bulletin, California State Commission of Horticulture, Vol. 3, pp. 449–455 (1914).

—sweet orange (*Citrus sinensis*) and sour orange (*Citrus aurantium*). Little consideration has been given to stocks in relation to differences in the environmental factors of soil, soil moisture, temperature, and humidity. Indeed, it may well be doubted if fifty per cent of the owners of California citrus groves have certain knowledge of the stock upon which their trees are growing.

Lack of such knowledge may seem of small moment to owners of trees of productive age. To prospective buyers, to persons setting out new acreage, and to nurserymen the question of stocks should be rated at its proper importance. Productiveness may be as dependent upon the nature and vigor of the stock used and its adaptability to soil environment as to any characters inherent in the buds grown upon such stock.

As illustrative of the practical bearing of the matter on the future success of the citrus grove may be cited examples of the variation in disease resistance of different stocks.

In the autumn of 1914 members of the Station staff inspected a nursery in southern California where sweet and sour orange stocks were being grown. An examination of one thousand trees of each kind showed 29 per cent of the sweet stock affected to some degree with gum disease. Not a single case of the malady was found among the sour stock. This evident difference in disease resistance under natural conditions supports the findings of Fawcett[2] that sour stock, artifically inoculated with fungi capable of inducing gummosis has an inherent constitutional resistance to the disease, which sweet seedlings do not possess.

In the spring of 1914, a seed-bed of about fifty thousand seeds was planted at Riverside, comprising seed of sweet orange, sour orange, trifoliate orange, pomelo, and rough lemon. Shortly after planting and continuing up to the time that the seedlings were attaining their first growth, the seed-bed was subjected to a severe attack of "damping off" by a soil fungus of the genus Rhizoctonia. A large percentage of the stock succumbed to this fungous invasion, but the noteworthy fact was the wide variation in the amount of injury done to the several blocks of stock.

That the fungus was rather uniformly distributed in the soil was demonstrated by a second planting on ground above the original area, with similar results. A careful estimate at the end of the season showed wide differences in the amount of injury sustained, indicated as follows:

[2] Fawcett, H. S., Monthly Bulletin, California State Commission of Horticulture, Vol. 2, p. 613 (1913).

Stock	Estimated percentage of loss
Sweet	65%
Trifoliate	60%
Sour	40%
Pomelo	30%
Rough lemon	1– 2%

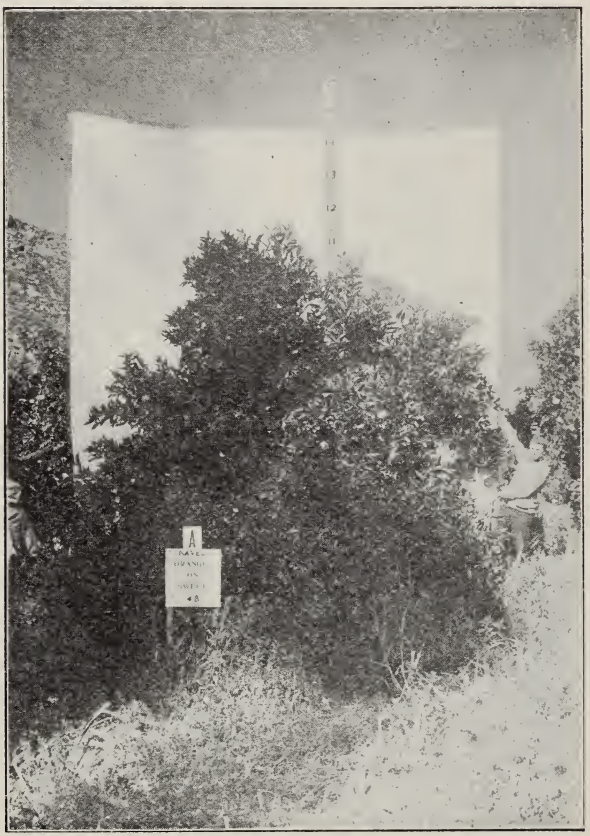

Fig. 1.—Navel on sweet stock.

STOCKS FOR CITRUS

The wide range of species and varieties of citrus grown for commerce, together with a correspondingly large number of the genus serviceable as stocks, opens a wide field for experimentation. With a marked variation in habit and in reaction to environment, the problem arises of determining some of the factors governing optimum root conditions and the relative compatibility of the several stocks and scions.

The two stocks most commonly used in propagating citrus trees in California are the sweet and the sour orange. In addition to these, pomelo has been employed to some extent, and ten or twelve years ago a considerable number of trees were budded on trifoliate orange stock. The rough lemon, so successfully employed in Florida, and the lime are practically unknown as stocks in California. More extended trials and a careful study of these lesser used stocks under varying conditions in this state are greatly needed before definite recommendations for specific varieties and soils will be fully warranted.

Sour orange (*Citrus aurantium*) has proved generally satisfactory as a stock. It is characterized by a well-developed root system which spreads and penetrates deeply into the soil; it is quite resistant to gum disease, as previously noted, and next to the trifoliate orange is the hardiest of the citrus stocks in common use. When trees budded on sour roots have been severely frozen, the tendency of this stock to send out an abundance of new shoots, which may be rebudded, is an advantage.

As a general rule, the quality of fruit produced on sour stock is of a high grade from the time the tree begins to bear. The yield for the first six or seven years may be somewhat lower than that of trees on sweet roots, according to the experience of some growers, but after that period production is said to increase and to hold its own with other stocks. Hume[3] is authority for the statement that old trees budded on sour stock will sometimes show an increase in diameter of trunk above the bud. Swingle[4] confirms Hume in the experience that the sour orange is antagonistic to the Satsuma orange because of some unexplained incompatibility between it and the stock in question.

The sweet orange (*Citrus sinensis*) is doubtless the stock in greatest use in California today if we include the considerable acreage of sweet seedling orchards and the sweet seedling groves that have been rebudded to the standard varieties. It bears the reputation in California, according to Mills,[5] of developing a more shallow root system than the sour orange. Like the latter, it sprouts readily from the trunk of the tree below the bud-union when the top has been frozen back, but unlike sour stock, it is markedly susceptible to gummosis.

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[3] Hume, H. H., "Citrus Fruits and Their Culture," p. 199. Orange Judd Co., 5th edition (1913).

[4] Swingle, W. T., "The Limitation of the Satsuma Orange to Trifoliate-Orange Stock," U. S. D. A. Bureau of Plant Industry, Circular 46, pp. 6–7 (1909).

[5] Mills, J. W., "Citrus Fruit Culture," California Agricultural Experiment Station Bulletin 138, pp. 11–12 (1902).

Most varieties on this root have proved to be vigorous growers under conditions insuring freedom from this disease. As a general rule sweet stock is less hardy than sour, but more so than pomelo.

The pomelo (*Citrus decumana*) has in recent years found vogue as a stock for oranges and lemons, and although preferred in some instances to sweet orange is not generally held in as high esteem as the

Fig. 2.—Navel on trifoliate stock.

sour root. Experience with pomelo seedlings indicate that they may be less resistant to drought than any of the stocks so far discussed. Some, however, have credited pomelo with the ability to thrive with little moisture. It has a vigorous root system and is not considered especially susceptible to gummosis. From his examination of tree roots Mills[6] concluded that pomelo stock produces more fibrous roots

[6] Mills, J. W., *loc. cit.*, p. 19.

than sweet or sour, and that the laterals develop somewhat deeper than those of the sweet orange. Growth of trees on pomelo stock is quite generally of a rapid and vigorous nature.

The rough lemon (*Citrus limonum*) is a stock practically unknown in California citrus culture. The experience of Florida growers has been such as to warrant a thorough experimental test with it in California. This stock is a seedling found growing wild in the Florida woods. It has proved especially suited for the conditions of some of the citrus sections of that state and possesses some qualities highly desirable for California if it is adaptable to the environment of this state. According to Hume[7] it is less hardy than either sweet orange or pomelo, and is unsuited to the northern sections of Florida. Its root growth is variable, some trees developing most of the fibrous roots near the surface; the general tendency, however, is the production of a large deep tap-root and spreading, well-distributed crown-roots. Its drought resistance is great. Buds on this stock at the Citrus Experiment Station have given a more rapid development than on any other root used.

This rapid growth is doubtless accountable for the fact that the first few crops from trees on rough lemon are of poor quality, being thick of skin and lacking in juice. After these first few crops, however, the undesirable qualities do not appear.

Rough lemon stock is also credited with ability to influence the shape of the tree grown upon it, tending to produce a tall, upright center.

Hume is again authority for the statement that rough lemon stock "has a marked influence on the fruitfulness of the Bahia navel orange in Florida. It is much more prolific on rough lemon stock and with the exception of the trifoliate orange, it is the only stock which can be recommended for the variety in that state. As a stock for pomeloes and oranges of the mandarin group, it is preferred by some growers to all others."[8]

Rough lemon, like the sour orange, is quite resistant to foot-rot, a form of gummosis common in Florida.

The trifoliate orange (*Citrus trifoliata*) was regarded with considerable favor as a stock in California about ten or fifteen years ago, but of late has not been held in universal esteem, owing to the varied results obtained therewith. It is an extremely hardy tree, being in fact the most resistant to cold of any of the genus known. According to Swingle,[9] it can withstand temperatures below zero Fahrenheit with-

[7] Hume, H. H., *loc. cit.*, pp. 200–203.

[8] Hume, H. H., *loc. cit.*, p. 203.

[9] Swingle, W. T., *loc. cit.*, p. 5.

out injury. It is deciduous in habit and has the reputation of imparting its hardiness in some degree to the varieties of citrus budded upon it. This, however, is a point not fully established in respect to California conditions. Its root growth is characterized by the production of a great abundance of fibrous roots of good soil penetrability. Unlike sweet or sour orange, the trifoliate orange has not a ready tendency to

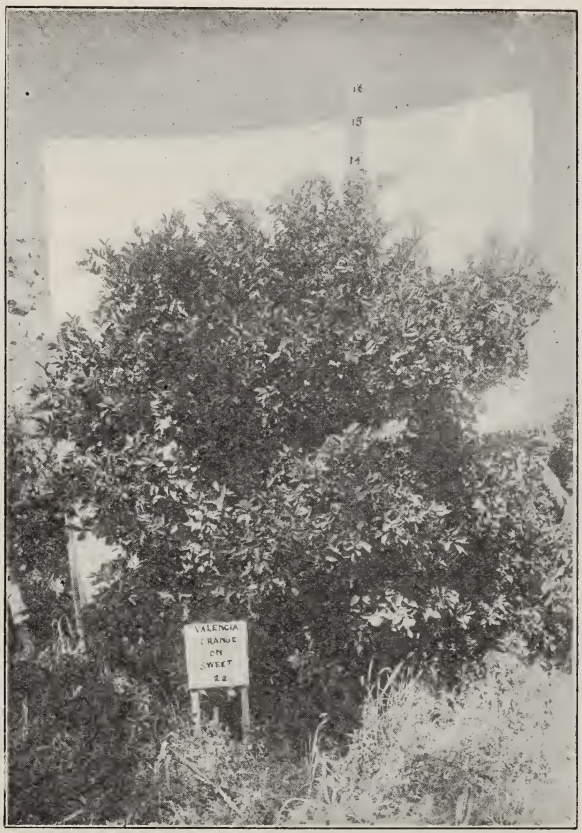

Fig. 3.—Valencia on sweet stock.

develop buds from the stocks when the tree upon it has been frozen back to the bud-union. It is generally recommended in Florida for clay soils and those of a heavy compact nature, as distinct from the drier type of calcareous formation.

An interesting development of the citrus industry in the Gulf States is the especial adaptability of *Citrus trifoliata* to the Satsuma orange. Swingle[10] emphasizes the fact that for this variety of the mandarin type,

[10] Swingle, W. T., *loc. cit.*, p. 7.

trifoliate is the only root that will insure a successful tree. Sweet orange, pomelo, and rough lemon stocks have been used with varying success, and sour orange stock for Satsuma is a most decided failure.

Williams[11] also lays stress upon the necessity of using trifoliate roots for Satsuma trees. The former, in his opinion, gives better growth of tree and yield of fruit. In addition, the fruit of trees of this variety on trifoliate roots has been found to be of superior quality and ripens somewhat earlier than that grown on other stocks.

For the kumquat (*Citrus japonica*), the trifoliate root is also to be recommended for satisfactory productiveness. Kumquats on sour roots result in vigorous but practically barren trees.

From the brief description of the different stocks and their characteristics just noted, the conclusion is naturally reached that despite their possible use over a considerable range of environment, a rather definite relationship must exist between the several stocks and factors of soil and climate. The experience arising from the development of the citrus industry in Florida and the Gulf States has in a general way outlined the geographical limitations of the several citrus stocks. Thus Rolfs[12] recommends for the heavy, moisture-retentive clays of Louisiana and Mississippi the trifoliate stock as unqualifiedly the best; likewise trifoliate for the eastern portion of northern Florida, where similar soil conditions prevail. Where the soil in this region is of a sandy type, some of the less hardy stocks have proved satisfactory. Pomelo root is given the preference over sour stock for the sandy soils of central Florida which have a rather high humus content. Sour orange is nevertheless recognized as somewhat hardier for this region.

For southern Florida the rough lemon is considered the stock par excellence. It is a prolific grower, subsisting on soils which, owing to meagerness of plant food, almost prohibit the use of other stocks.

For the heavier, non-calcareous soils of the southern portion of the state, pomelo and sour orange are preferred. They produce trees of slower growth than those on rough lemon, but yield fruit of better quality.

The marked predilection of the Satsuma orange for trifoliate stock, as already noted, makes this the chief stock for the commercial plantings of the Gulf States where that variety predominates.

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11 Williams, P. F., "The Satsuma Orange," Alabama (College) Experiment Station Bulletin 157, pp. 153–155.

12 Rolfs, P. H., "Citrus Fruit Growing in the Gulf States," U. S. D. A. Farmers' Bulletin 238, pp. 35–37 (1906). "Propagation of Citrus Trees in the Gulf States," U. S. D. A. Farmers' Bulletin 539, pp. 3–5 (1913).

Waschka[13] also prefers trifoliate to the other stocks for Texas conditions. According to his experience, oranges, pomeloes, and lemons on trifoliate are not only hardier but are more precocious and produce their fruit early in the season. Neither has he found that the trifoliate root dwarfs the tree.

Coit[14] recommends sweet or sour stock for the citrus regions of Arizona, and advises the use of trifoliate with reservations in view of the insufficient and varied experience with this root.

Fig. 4.—Valencia on sour stock.

The effect of *Citrus trifoliata* upon the subsequent development of the tree, *i.e.*, its possible dwarfing, is a moot question, so far as California experience has gone. The observations that have been reported

[13] Waschka, S. A., "Report of Progress with Citrus Fruits," Texas Agricultural Experiment Station Bulletin 118, p. 7 (1909).

[14] Coit, J. E., "Citrus Culture in the Arid Southwest," Arizona Agricultural Experiment Station Bulletin 58, pp. 303–305.

to this Station by growers are conflicting. It is impossible to draw valid conclusions therefrom because of the lack of comparable conditions or the absence of definite data. There are undoubted examples of dwarfed citrus trees on trifoliate roots; on the other hand there are, under apparently similar conditions, authentic instances of normal sized trees of the same variety on the stock in question. Hume takes the following stand on this point:

"Many writers on citrus propagation have stated without reservation that *C. trifoliata* stock dwarfs the top worked upon it. Exception must be taken to the breadth of this statement. It is not always true. Some varieties of citrus appear to grow as rapidly and attain as large a size when propagated on trifoliate orange stock as they do on sour or sweet. It will be found, however, that the fruit borne on young trees worked on trifoliate orange is usually superior in quality to that borne on trees budded on most other stocks, and it may be added that they are decidedly more precocious and prolific."[15]

In addition to the citrus stock experiment at this Station, but one other experimental plot, expressly laid out for the determination of data bearing on the question, is known to the writers. The work was undertaken by Mr. G. L. Taber, of Glen St. Mary, Florida. Hume[16] gives a detailed report of the data collected, of which the following is a general summary.

In March, 1899, Mr. Taber set out two acres of virgin land to citrus for a stock experiment. On this plot were planted 100 orange and pomelo trees, four trees of each of 25 varieties. Two trees of each set of four were budded on trifoliate stock, the other two on sour, with the exception of four varieties for which sweet stock was used; the stocks in each case alternating in the rows. Treatment of the plot was uniform throughout.

In June, 1901, 27 months after planting, all of the trees on trifoliate stock were bearing fruit, whereas 13 on sour stock bore none. The average number of fruits on sour stock was 13, on trifoliate 57. The average excess of height of tree on sour over those on trifoliate stock was one and one-quarter feet, and the average excess of breadth of tree on sour over trifoliate stock was one foot.

At the time that the data for the following year, 1902, were taken, 92 trees of 23 varieties were available for comparison. The following is a summary of results three years after planting: average height of trees on sour stock, 8 feet 2 inches; average height of trees on trifoliate stock, 6 feet 2 inches; average breadth of trees on sour stock, 9 feet 2

15 Hume, H. H., *loc. cit.*, pp. 205–207.

16 Hume, H. H., *loc. cit.*, pp. 207–216.

inches; average breadth of trees on trifoliate stock, 7 feet; average yield for two years on sour stock, 69 fruits per tree; on trifoliate stock, 93 fruits per tree. Out of 23 varieties, two varieties of oranges and one of pomelo averaged larger on trifoliate than on sour stock at the end of the third year, and eight other varieties on trifoliate stock compared favorably with sour stock in respect to growth.

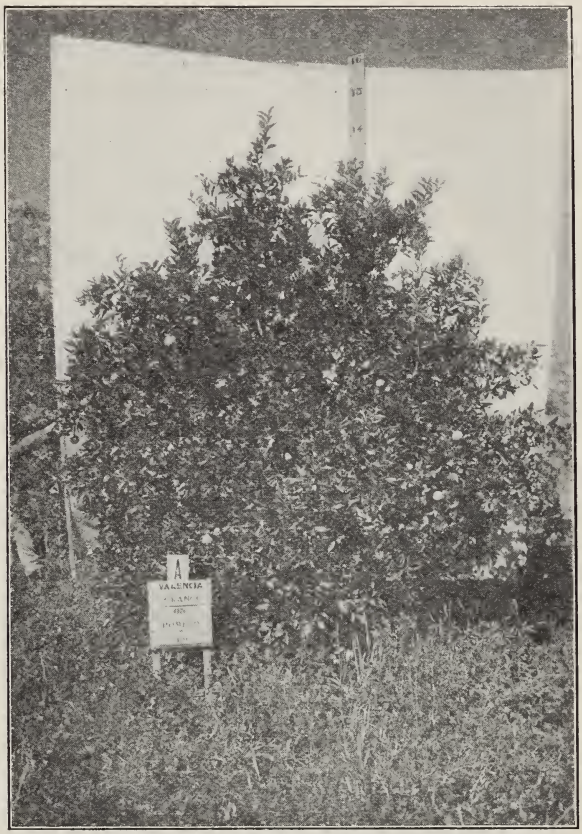

Fig. 5.—Valencia on pomelo stock.

Mr. Taber concludes his report of the results up to 1902 as follows:

"One thing has been fully determined, and that is that all varieties come into bearing at a very early age when budded upon *Citrus trifoliata.* Another thing that is fully determined is that the fruit from trees on *Citrus trifoliata* roots is fully equal in quality to the same variety on sour roots, and still another thing that experience has proven is that the same varieties ripen earlier in the season on *Citrus trifoliata* than upon sour stock. The longevity of the trees on *Citrus trifoliata,* the ultimate size that they will attain, and their comparative value, in the long run, with those on sour stock, remain to be proven.

It is probable that as the trees get older there will be more difference in size between trees on the two stocks than is now apparent. This will be the natural consequence of the trees fruiting so heavily when young. This smaller ultimate size of trees is a quality, whether advantageous or otherwise, which everyone can figure out for himself. It admits of close planting and a consequent heavy crop from a given acreage. It is also probable that some varieties will show more affinity for the trifoliate stock than others, and that while some varieties will prove permanently successful on this stock, others may not. The exact extent to which extra hardiness is induced by using *Citrus trifoliata* stock is also more or less conjectural, but experience has shown that the claim for extra hardiness is well founded, with certain varieties. Whether it will prove equally so with all varieties is one of the points that further careful comparisons in the test orchard must determine. The test orchard established is one of those long time experiments in which years must pass before actual definite comparisons can be made that will cover all the points involved.''

In a letter received from him about a year and a half ago (November 6, 1913), Mr. Taber writes:

''Brought up to date and summarized, I might say that all varieties budded on *Citrus trifoliata* have shown remarkable fruiting qualities both as to the earliness in which the trees come into bearing and as to their persistency in fruiting year after year. This persistent fruiting quality tends in some varieties to reduce the size of the trees, which is only a natural consequence. In other varieties there seems to be but little difference in the size of the trees as between *Citrus trifoliata and* sour stocks.

''The fruit on *Citrus trifoliata* is uniformly of good quality, with less coarse skinned rough fruit than that on the same varieties on sour stock.

''Rather heavy, moderately damp land is better suited to *Citrus trifoliata* than high sandy ridges. Also the northern limit of successful orange culture seems better adapted to *Citrus trifoliata* than the hotter climates.''

CITRUS STOCK EXPERIMENT AT THE RIVERSIDE STATION

This investigation was begun at the Citrus Experiment Station in April, 1907, in accordance with plans prepared by Professor Ralph E. Smith, assisted by Mr. J. W. Mills and Mr. Thomas Francis Hunt. Until 1912 the work was carried on by Mr. J. H. Norton, chemist in charge, later by Dr. J. Eliot Coit, and since December, 1912, by the authors. The junior author has also had charge of the cultural operations and the picking and grading of the crops.

The trees comprising this experiment are planted in two separate plots. The smaller, adjacent to the present Station building on the north, will in the ensuing discussion be designated as plot A. The larger plot, B, is located in the southeastern section of the experimental citrus area east of the present headquarters.

Plot A consists at present of 49 trees, plot B, of 164 trees. The varieties used are Washington navel and Valencia oranges, and Eureka lemon. The stocks upon which these are budded are sweet orange, sour orange, trifoliate orange, and pomelo.

Differences in soil conditions necessitate a separate consideration of the two plots and a further division of plot B into two sections. Both

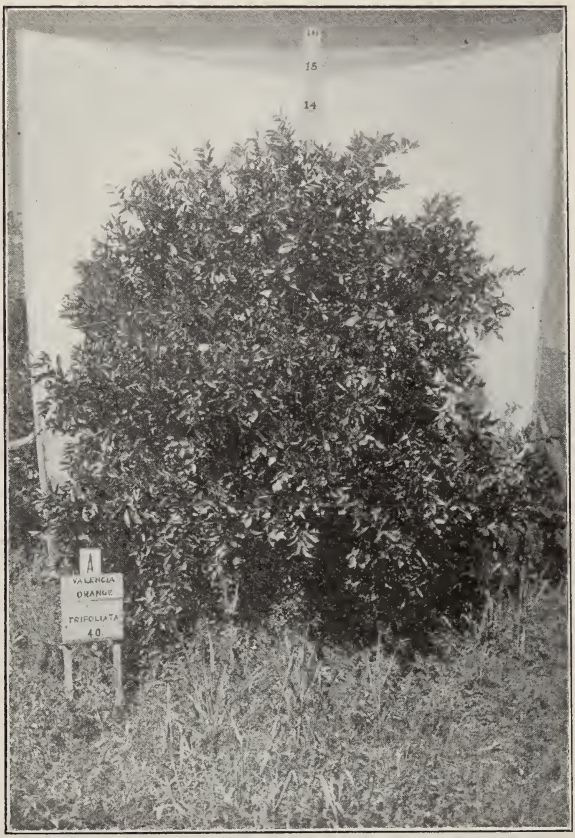

Fig. 6.—Valencia on trifoliate stock.

main plots have the same general slope and drainage. The top soil is dissimilar. In A it consists of a light, deep granitic loam, uniform in nature. That of B is somewhat heavier and approaches a clay loam in character.

The subsoil in A is deep and does not differ substantially from the overlying strata; that of B is a pervious, sandy loam with wide variations in depth. It is this last named factor that necessitates a division

of B in considering the data to follow. In a portion of this plot the top soil is underlaid by hardpan of the most impervious character at depths varying from 15 inches to a little over 3 feet. A soil survey established the respective deep and shallow areas, and the tree data have been grouped in accordance therewith. Future reference will therefore be made to the two divisions of this plot as B "deep" and B "shallow." It is thus evident that for purposes of comparison there are essentially three plots to be considered.

The number of trees of each variety on each of the several stocks in the respective plots is as follows:

TABLE I

Plot	Variety	Stock	Number of trees
A	*Washington navel orange,	Sweet	5
		Trifoliate	5
	Valencia orange,	Sweet	5
		Sour	5
		Pomelo	5
		Trifoliate	5
	Eureka lemon,	Sweet	5
		Sour	5
		Pomelo	4†
		Trifoliate	5
	Total		49
B‡ "deep"	Washington navel orange,	Sweet	29
		Sour	8
		Trifoliate	8
	Valencia orange,	Sweet	9
		Sour	4
		Pomelo	7
		Trifoliate	9
	Eureka lemon,	Sweet	6
		Sour	8
		Pomelo	3
		Trifoliate	8
	Total		99

* Plot A had originally 5 navels on sour stock. Early in the course of the work it was found necessary to transplant this row, which excluded it from the experiment.

† One of the five lemons on pomelo in this plot failed to grow.

‡ A number of trees of the several varieties on different stocks in both sections of B have succumbed to cold or disease. This accounts for the varying numbers in the groups.

B "shallow"	Washington navel orange,	Sweet	11
		Sour	5
		Trifoliate	6
	Valencia orange,	Sweet	6
		Sour	7
		Pomelo	5
		Trifoliate	6

Fig. 7.—Eureka on sweet stock.

Eureka lemon,	Sweet	4
	Sour	5
	Pomelo	4
	Trifoliate	6
Total		65

The trees are set in variety blocks, the respective stocks forming separate rows.

The trees in all divisions were set out in April, 1907, as two-year old buds of about 1 inch caliper, purchased from one nursery, and were selected for apparent uniformity of condition. They have received uniform treatment with respect to cultural practices. The data for fertilization and cover-crops follow:

TABLE II

FERTILIZER AND COVER-CROPS, 1907–1914

Year	Fertilizer	Amount per tree	Winter Cover-crop
1907	Commercial fertilizer		Vetch (*Vicia sativa*)
	4% N 8% P_2O_5 4% K_2O	2 lbs.	
1908	Commercial fertilizer		Vetch (*Vicia sativa*)
	4% N 8% P_2O_5 4% K_2O	2 lbs.	
1909	Commercial fertilizer		Vetch (*Vicia sativa*)
	4% N 8% P_2O_5 4% K_2O	2 lbs.	
1910	Superphosphate (18.4%)		Vetch (*Vicia sativa*)
	Available P_2O_5	5 lbs.	
	Manure	4 cu. ft.	
1911	Raw rock phosphate	5 lbs.	Vetch (*Vicia sativa*)
	Manure	5 cu. ft.	
1912	Raw rock phosphate	5 lbs.	Vetch (*Vicia sativa*)
	Manure	5 cu. ft.	
1913	Raw rock phosphate	8 lbs.	*Vetch (*Vicia sativa*)
	Manure	6 cu. ft.	
1914	Raw rock phosphate	12 lbs.	Purple Vetch (*Vicia atropurpurea*)
	Manure	5 cu. ft.	

* *Melilotus indica* took the place of vetch on Plot A for the year 1913.

The data derived from the experiment to date are concerned with three of the more important considerations bearing on the effect of stock upon scion. These are yield and commercial quality of fruit, and vigor of tree. The manner of obtaining the first of these is self-evident; quality in this case does not refer to intrinsic properties, such as flavor, texture of pulp, or percentage of "rag," but relates to market standards, which take into account size of fruit, texture of rind, and freedom from blemishes.

For determining the data on these points, the fruit of each tree was picked separately. It was then separated according to market sizes by a mechanical grader, and every fruit then carefully examined for quality and for defects of rind.

The weight of every tree crop was also noted, inasmuch as the

average weight and number of fruits will serve the experienced grower in a general way as an index of the average size of the fruits.

Growth of trees in terms of volume was taken as an index of vigor. The methods used in the determinations will be considered later.

The average yield of fruit per tree, both in number and weight, has been based on the number of trees in each division and the number of actual crops produced by the same, instead of the actual number of

Fig. 8.—Eureka on sour stock.

seasons. This is believed to be the fairest basis of comparison, in view of the fact that although a majority of the sections have yielded four crops, from 1910 to 1914, inclusive, six have borne fruit in but three. Especially is this the case with Eureka lemon, the failure of the 1913 crop of this fruit in plot B, and an almost negligible yield in A, being undoubtedly due to the severe cold wave of January, 1912.

The crop year coincides with that established by the California Fruit Growers' Exchange, which begins November first.

TABLE III

Average Yield of Fruit, 1910–1914

Washington Navel Orange

Plot	Stock	No. of trees	No. of crops	Average no. fruits per tree	Average no. lbs. per tree	Per cent Fancy	Per cent Choice	Per cent Standard	Per cent Culls
A	Sweet	5	4	116.35	44.30	34.65	34.63	25.17	5.53
	Trifoliate	5	4	68.30	27.96	40.95	33.23	21.57	4.26
B	Sweet	29	4	77.90	27.96	26.72	36.84	30.36	6.08
Deep	Sour	8	4	110.59	41.19	20.17	37.75	34.67	7.43
soil	Trifoliate	8	4	78.16	31.66	24.67	41.31	29.50	4.55
B									
Shal-	Sweet	11	4	48.05	14.38	22.04	35.33	33.94	8.69
low	Sour	5	4	71.10	23.73	23.35	38.05	31.56	7.04
soil	Trifoliate	6	4	43.75	17.94	24.58	39.97	30.77	4.68

TABLE III—(*Continued*)

Valencia Orange

Plot	Stock	No. of trees	No. of crops	Average no. fruits per tree	Average no. lbs. per tree	Per cent Fancy	Per cent Choice	Per cent Standard	Per cent Culls
A	Sweet	5	4	178.90	72.18	53.48	27.64	15.41	3.20
	Sour	5	4	126.85	51.39	43.68	29.31	21.62	5.41
	Pomelo	5	4	168.90	69.47	45.89	29.15	21.91	3.05
	Trifoliate	5	4	159.95	64.82	41.65	31.66	20.75	5.94
B	Sweet	9	4	90.72	35.84	25.39	40.09	31.47	3.04
Deep	Sour	4	3	135.75	55.91	23.16	44.21	30.44	2.18
soil	Pomelo	7	4	108.71	43.32	24.10	40.03	33.08	2.82
	Trifoliate	9	4	173.67	62.20	22.35	41.86	28.75	7.04
B	Sweet	6	4	86.33	31.39	27.17	40.75	28.58	3.47
Shal-	Sour	7	4	74.39	28.30	20.18	39.05	37.99	2.76
low	Pomelo	5	4	59.75	23.14	24.55	38.59	33.62	3.24
soil	Trifoliate	6	4	63.88	21.11	17.01	39.79	29.28	13.93

TABLE III—(*Concluded*)

Eureka Lemon

Plot	Stock	No. of trees	No. of crops	Average no. fruits per tree	Average no. lbs. per tree	Per cent Fancy	Per cent Choice	Per cent Standard	Per cent Culls	Per cent Tree-ripes
A	Sweet	5	5	71.80	20.23	34.35	35.74	19.82	7.27	2.77
	Sour	5	5	98.20	27.39	34.65	34.90	20.77	6.90	2.74
	Pomelo	4	5	100.45	28.03	29.72	36.92	21.01	9.13	3.18
	Trifoliate	5	5	52.76	14.67	13.29	19.22	31.70	31.83	3.89
B	Sweet	6	3	41.61	11.56	21.19	44.64	18.51	11.59	4.07
Deep	Sour	8	3	44.33	12.29	21.32	40.28	19.85	14.40	4.15
soil	Pomelo	3	3	34.89	9.75	17.33	42.67	16.72	20.82	2.49
	Trifoliate	8	4	24.53	6.81	2.79	24.23	28.78	40.97	3.23
B	Sweet	4	4	37.69	10.21	15.77	38.49	19.00	15.28	11.46
Shal-	Sour	5	3	41.27	11.21	19.71	39.61	20.07	12.49	8.12
low	Pomelo	4	3	20.67	5.75	4.17	42.78	20.35	29.39	3.30
soil	Trifoliate	6	4	29.83	8.14	6.39	23.96	30.96	32.06	6.63

A study of the figures above shows no evidence of significant differences in the quality of oranges produced by the respective varieties on the several stocks. The percentage of each grade for any one variety in the same section appears to have no relation to the particular root; seldom are such differences greater than 4 or 5 per cent. The one exception is Valencia on pomelo, B "shallow," where "fancy" fruit

Fig. 9.—Eureka on pomelo stock.

of trees on trifoliate falls considerably below the same grade from trees on sweet and pomelo stock. It is not much below the grade per cent of fruit on sour stock.

Quality differences are more evident in the case of the lemon. Here we may note that although the respective grades run closely to each other for sweet, sour, and pomelo stocks, they fall off noticeably in each block when trifoliate root has been used. There is a lower percentage

of fancy and choice, and a relatively higher amount of standard and cull fruit. Here again there is an exception to this general statement in the case of pomelo in B "shallow," where the percentage of "fancy" is less than that from trees on trifoliate. This exception, as well as the one indicated for Valencia orange, is not entitled to much weight, inasmuch as the "shallow" section of B represents abnormal conditions.

The yield of fruit, considered either from the values of number or weight, shows more striking deviations. In plot A the yield of navels on sweet stock is almost double that of the variety on trifoliate. In both sections of B, on the other hand, the two roots have produced practically equal results, and both are exceeded by sour stock by a wide margin.

Different rank is again evident in the case of the Valencia orange. In Plot A sweet stock is easily first, pomelo a close second, trifoliate not far behind the latter, and sour stock considerably lower than any of the others. The order is almost reversed in the "deep" section of B, where trifoliate exceeds sour, pomelo is third, and sweet stock is here lowest of all in yield. Still another order obtains in b "shallow."

For a comparison of the varying effect of the stock upon the growth of the tree, the volume of the top was taken as a sufficiently close index. This was ascertained with the regulation fumigation tent used in combatting the scale insect pests of the citrus regions. The greatest circumference of the tree under the tent and the measurement "over" it were taken. The latter is the linear expression of the periphery of that portion of a vertical plane passing through the highest point of the tree and extending from the surface of the ground on one side to the other. Although the volume obtained in this manner is not an exact measurement of the tree volume, since it includes the variable space between the lowest growth of the tree and the surface of the earth, it is nevertheless sufficiently close for purposes of comparison.

By substitution of the dimensions above referred to in Woglum's[17] formula, the volume under the tent is obtained in cubic feet.

[17] Woglum, R. S., "Fumigation of Citrus Trees," U. S. D. A., Bureau of Entomology, Bulletin 90, Part I, p. 28.

$$\text{Volume in cubic feet} = \frac{C^2}{4\pi}\left(\frac{O}{2} - \frac{C(3\pi - 4)}{12\pi}\right)$$

C = circumference of tree,
O = distance over top of tree.

TABLE IV

AVERAGE VOLUMES OF TREES (CUBIC FEET) IN 1914

	Plot	A	B Deep	B Shallow
Washington Navel Orange	Sweet	1061	583	420
	Sour	.....	551	440
	Trifoliate	695	525	341
Valencia Orange	Sweet	1128	790	676
	Sour	788	592	499
	Pomelo	1112	730	577
	Trifoliate	818	786	335
Eureka Lemon	Sweet	1434	998	807
	Sour	1032	698	713
	Pomelo	1270	693	378
	Trifoliate	199	164	167

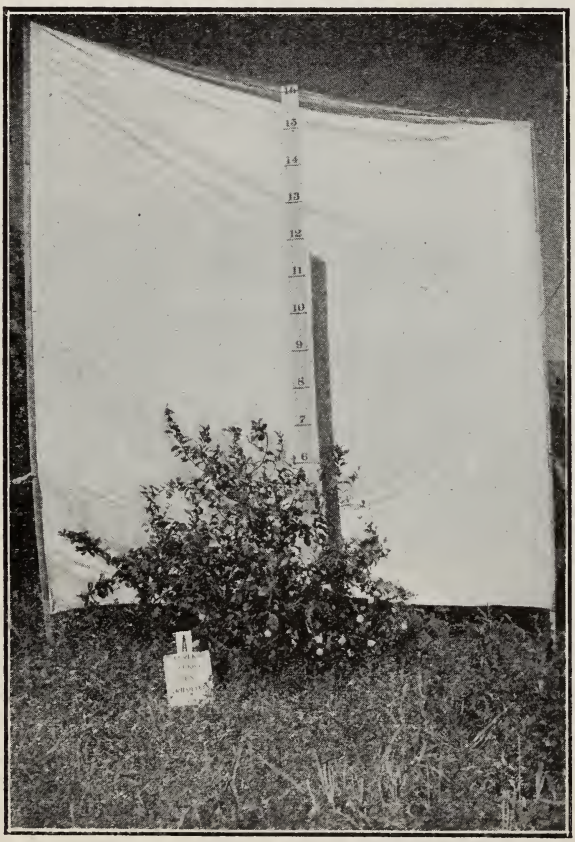

Fig. 10.—Eureka on trifoliate stock.

The data on size of trees is of especial interest in view of the reputation that *Citrus trifoliata* stock has gained for dwarfing the tree.[18]

In plot A navels on trifoliate average practically one-third smaller than the trees on sweet stock. In B "deep" the differences between the three stocks are, for all practical purposes, negligible.

Valencias in plot A have attained almost equal size on sweet and pomelo roots, and trifoliate has produced a larger tree than sour stock. In B "deep," on the other hand, Valencia on trifoliate is practically as large as the variety on sweet root, the difference in average volume amounting to but 4 cubic feet. The use of sour stock has here resulted in the smallest growth, pomelo stock exceeding it.

The most striking effect, however, is to be seen in the Eureka lemon sections of both plots. In A, sweet stock has produced the largest tree, pomelo stock ranks second, and sour stock third. The trifoliate root has here produced a most remarkable dwarfing of the tree. Almost the same relative positions and values hold in the deep section of B. In this case sour stock slightly outranks pomelo. The values for B "shallow" are not consistent with those just considered, and this is undoubtedly due to the irregular and wide deviations in the depth of the soil over the hardpan.

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[18] In numerous instances following the freeze of January, 1913, the slightly increased hardiness of varieties grown on trifoliate root stocks was observed. This increase in hardiness was not sufficiently great to be of importance in California in view of the unsatisfactory growth that our principal varieties apparently make on this stock, but is a factor that may be of importance in other localities.

The following notes recorded by Prof. R. S. Vaile of the Citrus Experiment Station are also of interest in considering the effect of trifoliate stock.

Notes on trifoliate Root Stock. January to May, 1915

"Morris Smith Grove, West Orange-Thorpe Avenue, Santa Ana, just west of Orange Thorpe School.

"Six year old Valencias on trifoliate root—have seemingly been well cared for. Are very badly stunted, growing close to ground without characteristic long straight leaders of normal Valencias.

"Bishop Property on Fairhaven Avenue, Orange, Calif.

"Four or five Valencia resets six years old on trifoliate root stock. Have made not to exceed one-half the growth of other trees on sweet root set at the same time.

"Rancho Sespe, Fillmore.

"A considerable block of Eureka lemon trees planted on trifoliate root. Difference in size between these trees and adjoining trees on sweet or sour root was very marked at five years of age. Foliage was lighter in color and less vigorous on trifoliate. Trees finally replaced with new ones on sour root.

"Douglas Grove, East Badillo Avenue, Covina.

"Twenty-five year old Valencia Grove, medium heavy soil. Most of trees are very large. Block of about 50 trees near center of grove decidedly stunted in comparison. No apparent differences in soil to depth of 4 feet. These smaller trees are on trifoliate stock, while others are on either sweet or sour orange.

"H. J. Webber."

DISCUSSION

A consideration of the table of comparative yields makes it clear that these data are purely indicative and in no sense proper as a basis for definite conclusions. The yields indicated are in all cases extremely small, even for average values. This is of course primarily due to the

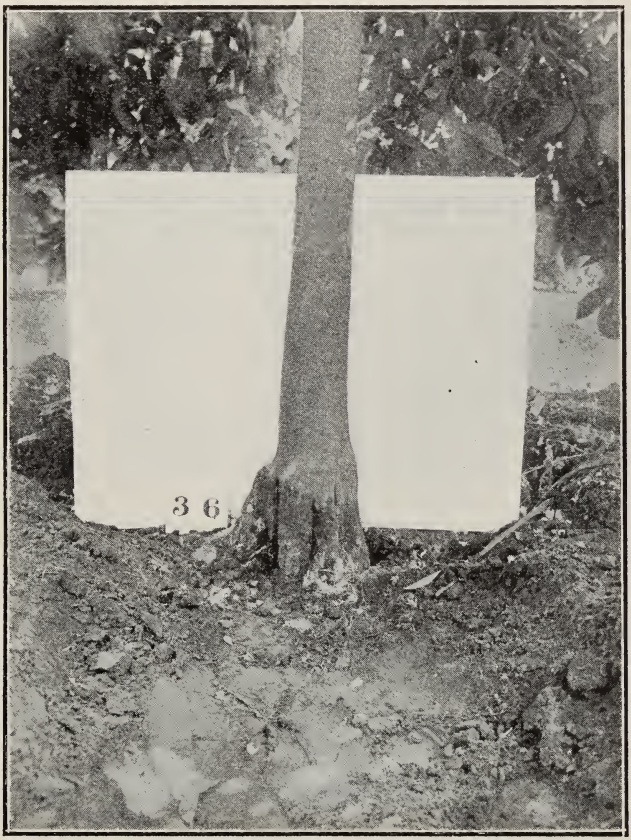

Fig. 11.—Valencia on trifoliate stock, showing effect of scion on stock (increased diameter of trunk below bud-union).

fact that the figures are those of the first years of production in the life of the trees; the very low yield of the first year or two has naturally reduced the average for the five years to a considerable degree. Allowance must also be made for the severe cold waves of December, 1911, and January, 1913, which may have had their effects upon the succeeding bloom and crops. This is undoubtedly true in the case of the lemon yields.

It is evident, however, that there is no ground at present for recommending any particular stock for increased yield or quality of fruit of either of the oranges or the lemon used in these experiments. Such evidence could scarcely be expected at the end of the first half-decade of an experiment the nature of which demands an accumulation of many years' data as a prerequisite for sound conclusions. Assuming a future

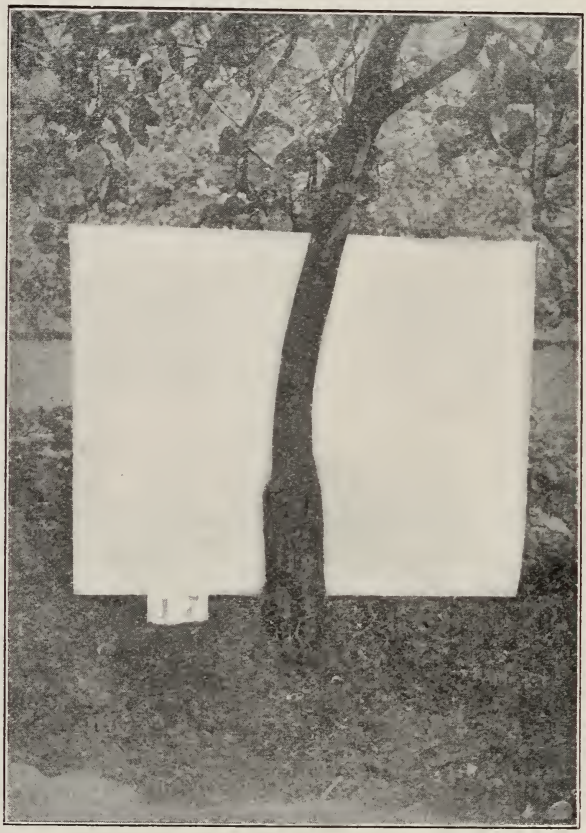

Fig. 12.—Eureka lemon on trifoliate stock, showing effect of scion on stock (increased diameter of trunk below bud-union) in addition to dwarfing effect of stock on scion.

increased annual production consistent with the increasing age of the trees, we may properly look for more differences between the yields of trees on different stocks in the averages of the next five or ten years, if such differences are to become evident under the conditions of the experiment. Moreover, any factor making for reduction in yield or quality of fruit, or in size of tree, which may be associated with early

growth—a characteristic accredited to sour stock, for example—should disappear in the future records.

Conclusions regarding the superiority of any one stock for its effect upon growth are likewise wholly unwarranted at present. Attention is called to the fact that the behavior of the orange, both navel and Valencia, has varied on the two plots in regard to the size of trees on trifoliate and the other stocks, and that in no case has the use of the former effected a marked or undesirable dwarfing. (Figures 1–6). Valencia has been particularly thrifty on the trifoliate root. Indeed, the most striking fact of the experiment evident to date is that *Citrus trifoliata per se* does not necessarily dwarf all species or varieties budded upon it. Where such dwarfing occurs, it is highly probable that conditions of environment are largely responsible. Further and more extensive investigation of these stocks on a number of widely different soil types is essential for a final answer to this question.

On the other hand, the dwarfing of Eureka lemon on trifoliate root has been so extreme and so consistent that we may justifiably regard it as highly undesirable for that fruit. (Figures 7–10).

A point of interest in connection with the use of *Citrus trifoliata* as a stock is the characteristic increase of the diameter of the trunk below the bud-union. (Figure 11). This seems to be a constant result of the union of the comparatively small root system, accustomed normally to develop a small tree, with the bud of a species of large growth. Such evident root stimulus appears in the trifoliate stock irrespective of the variety of orange or lemon budded upon it. In the case of the latter the increase of trunk persists even when the counter effect results in the dwarfing of the tree. (Figure 12).

It must be pointed out in conclusion that this Station, despite the favorable results so far obtained with the trifoliate orange as a stock for oranges, cannot recommend it at present, in view of the fact that well-defined cases are known where its use has been injurious. In the absence of further knowledge, with the limited data at hand, the use of either sweet or sour stock is, therefore, to be recommended on grounds of wide and successful experience of California growers. Where conditions are favorable for the development of gummosis, sour stock should be given the preference.

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